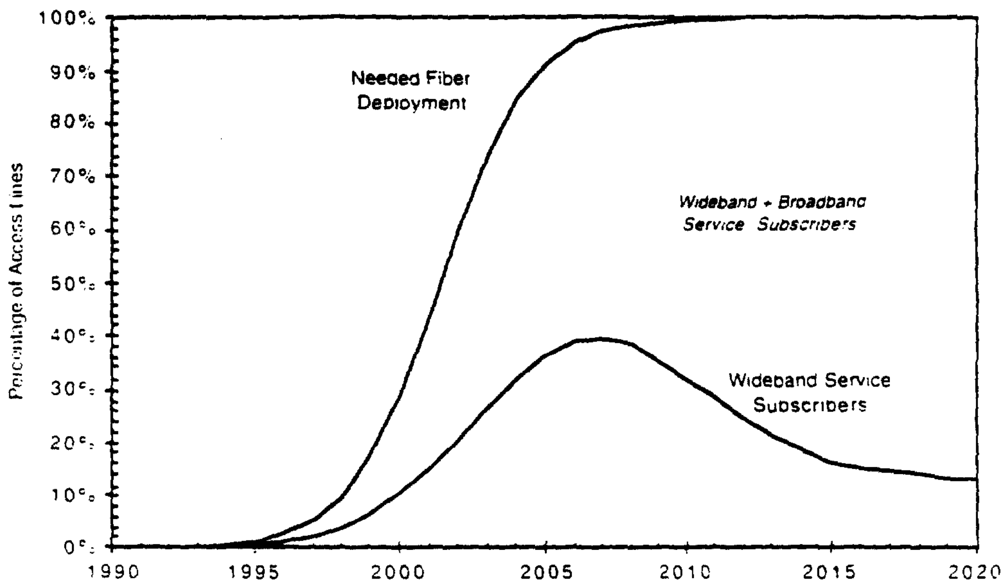
The middle scenario represents a balancing act for the LECs. If they over-invest in upgrading copper, they risk entering the next century with an obsolete network after having sunk large amounts of money into equipment to enhance the copper technology. On the other hand, they cannot get fiber to everyone simultaneously, and, even if they could, it might not be the best plan financially. The middle scenario avoids the two extremes, with wideband services being provided on copper in the early years, then migrating to fiber as demand increases and costs continue to fall.

Exhibit 7

Distribution Fiber to Meet New Services Demand



Source: Technology Futures, Inc.

Exhibit 7 (Continued)
Distribution Fiber for Broadband Services

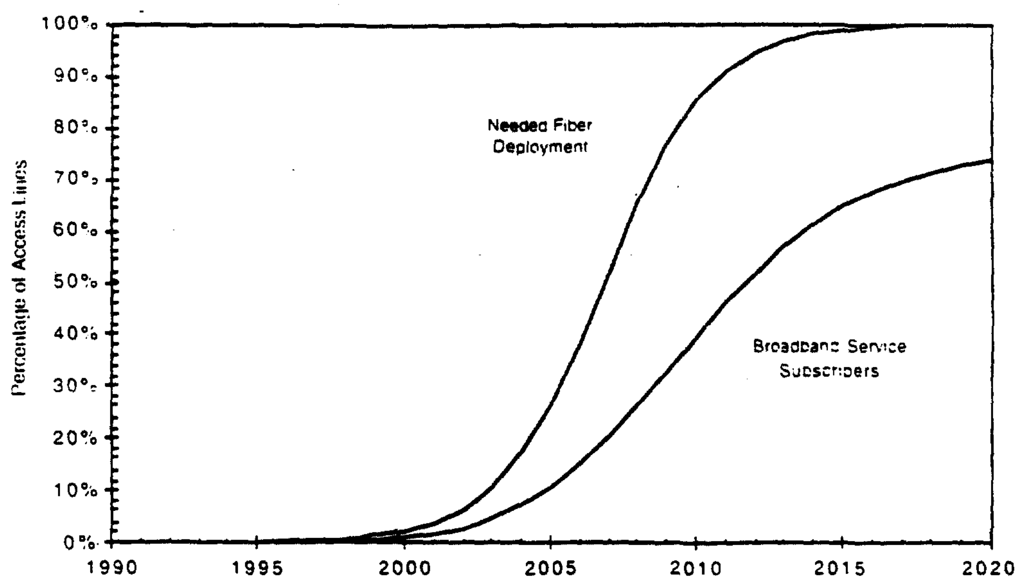
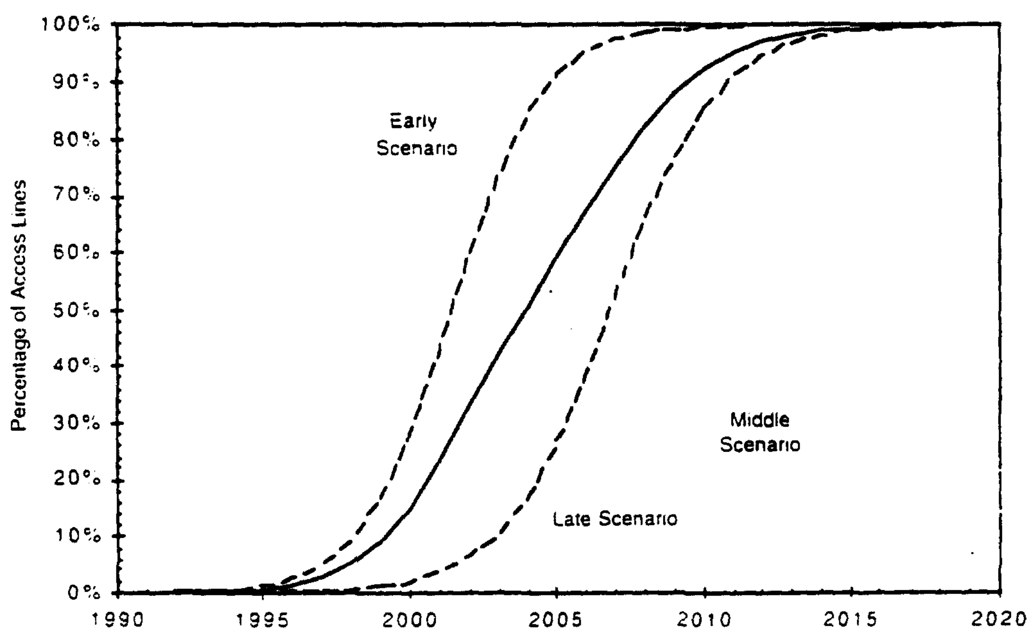


Exhibit 8
The Adoption of Distribution Fiber—Three Scenarios



Source: Technology Futures, Inc.

Adopting fiber more slowly than in the middle scenario would require too large of an investment in ADSL/HDSL and divert excessive resources away from the preferable, long-term technology—FITL. With the competition deploying more efficient technology and offering higher-quality services, this would be a dangerous course. For this reason, we believe that the middle scenario implies the maximum rational deployment of interim technologies and that the late scenario is not a reasonable choice.

However, this does not mean that the middle scenario is necessarily the best choice either. For companies that want to realistically compete in the provision of standard cable television services, as opposed to what has been called VCR-quality interactive services, the early scenario is better. Also, regardless of cable television services, many companies will adopt fiber strategies that will be much closer to the early scenario because, given the increasingly competitive nature of the industry, this is a less risky strategy. For these reasons, we believe that the likely industry FITL adoption pattern will fall between the early and middle scenarios.

The result is an industry ARL of 10.2 years (as of 1/1/95) for copper distribution facilities for the companies that adopt fiber according to the middle scenario. Companies that aggressively adopt fiber optics will experience an ARL of about 7.5 years.[11] We believe that competitive forces in the industry will tend to move the industry as a whole closer to the early scenario. These estimates do not take into account the impact of competition. TFI's 1995 competitive impact study showed that competition from wireless technologies and cable television could reduce remaining economic lives for copper cable to between two and five years, even under the average fiber adoption scenario.[12]

Metallic Cable, Composite Lives

Ignoring competition, we recommend average remaining lives of 2.9 years for interoffice copper, 7.0 to 7.8 years for copper feeder, and 7.5 to 10.2 years for distribution. About 5% of current metallic outside plant investment is in interoffice facilities, with the remainder divided equally between feeder and distribution. Thus, a composite ARL for copper outside plant should be between 7.0 and 8.7

[11] See Table 3.3 in Attachment 3 for ARL computations.

[12] L. K. Vanston and C. Rogers, *Wireless and Cable Voice Services: Forecasts and Competitive Impacts* (Austin, TX: Technology Futures, Inc., 1995).

years.[13] For a typical company, this would correspond to a projection life of between 14 and 16 years for the installed base of equipment. A range of projection lives are provided since a specific projection life corresponding to the industry ARL depends upon age, distribution, and curve selection.

As an example, underground cable is mostly interoffice and feeder, and an ARL of 6.6 to 7.3 years is recommended for that account.[14] For a typical company, this ARL corresponds to a projection life of between 13 and 15 years for the installed base of equipment. It should be noted that the projection life depends on curve assumptions and the average age of plant, which will be unique for each company.

Lives for Fiber Cable

Although there continue to be significant technological improvements in fiber optic cable, it is not yet clear how much of today's single-mode fiber will be replaced when superior technology becomes available. Much of the multimode fiber installed in the early days of fiber has been replaced with single-mode fiber. With such an historical precedent, we cannot rule out technology-driven replacement of fiber cable. However, with the exception of the multimode to single-mode transition, upgrades to existing fiber systems have concentrated on the associated electronics. For this reason, we did not apply the same type of substitution analysis that we did for the other accounts. This is not to say, however, that fiber investment will have especially long lives.

As identified by GTE Labs and Bellcore, there are four major factors impacting fiber lives: technological obsolescence, topological obsolescence, mechanical degradation, and optical degradation. Technological obsolescence is to be expected even if the successor technology is not obvious today. We have already seen one generation of fiber optics be replaced, as multimode fiber made way for single-mode fiber. Also, manufacturers continue to improve the basic properties of fiber such as flexibility, strength, clarity, transmission quality, reflectivity, refractivity, and durability. Topological obsolescence is where the location, routing, sizing, or architecture of a fiber installation later proves wrong. Finally, fibers eventually will

---

[13] This is a weighted average. For the lower value: 5% × 2.9 years + 47.5% × 7.0 years + 47.5% × 7.5 years = 7.0 years. For the higher value: 5% × 2.9 years + 47.5% × 7.8 years + 47.5% × 10.2 years = 8.7 years.

[14] This is a weighted average computed from the relative investments in feeder and interoffice facilities. For the lower value: 10% × 2.9 years + 90% × 7.0 years = 6.6 years. For the higher value: 10% × 2.9 years + 90% × 7.8 years = 7.3 years.

crack or "go dark" with age, causing degradation in transmission capability. Although more careful fiber specification and installation has improved fiber lives, eventual wear-out is still a factor.[15] Putting these factors together, the best available technical judgment indicates that the projection life of fiber should be 20 years and that anything more puts the recovery of capital in jeopardy.[16]

Because of competition, any investment in the local exchange network now has an element of risk. The investment and accounting communities must reflect this risk in evaluating assets.[17] Although, from a technological viewpoint, a projection life of 20 years is appropriate, there should be a downward adjustment for the risk factor. Obviously, the appropriate amount involves some judgment that strays from the realm of both mortality analysis and technology forecasting, but five years may be a reasonable adjustment. Thus, a life of 15 to 20 years is recommended, depending on whether the risk factor is considered.

Lives for Digital Circuit Equipment

The digital circuit equipment account includes a variety of different equipment types, some very modern and some quite old and nearing obsolescence. However, virtually *all* circuit equipment will be impacted by SONET technology. Thus, forecasting the adoption of SONET allows us to calculate an upper bound on the productive life of any type of circuit equipment.

Exhibit 9 shows our forecasts of the percentage of capacity on SONET for the interoffice and loop environments, respectively. These forecasts are based on the Fisher-Pry model applied to estimates and planning data from nine LECs, shown by the hollow boxes. By 2005, essentially all currently-deployed digital circuit equipment will have been replaced by SONET equipment. Combining the interoffice and loop forecasts implies a weighted ARL for digital circuit equipment of

[15] The physical properties of fiber are very different from those of copper, and their physical lives are affected by different factors. Thus, historical copper lives provide no guidance in estimating fiber lives.

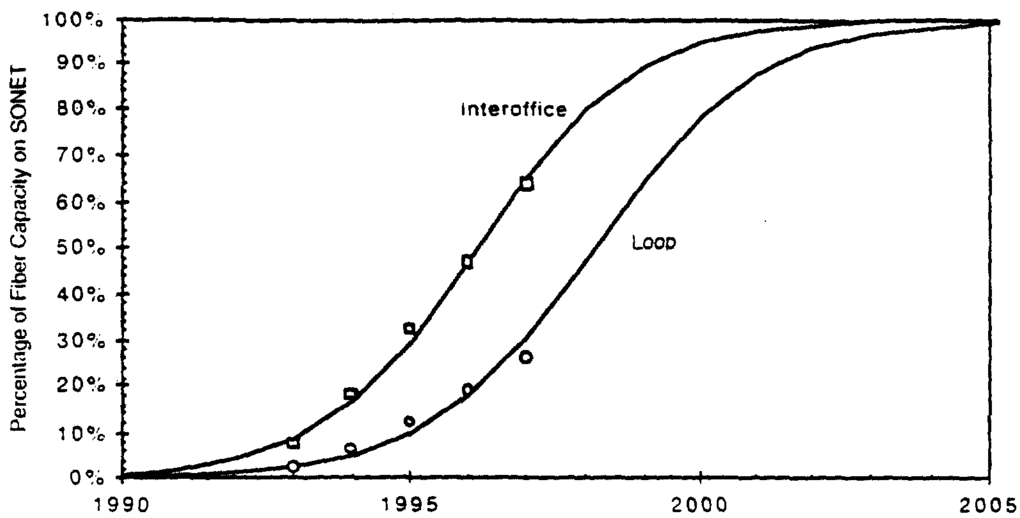
[16] C. M. Lemrow, Corning Glass Works, "How Much Stress Can Fiber Take?," *Telephony* (May 23, 1988):82. Also, Bellcore Technical Advisory Committee, *Generic Requirements for Optical Fiber and Optical Fiber Cable*, Issue 8 (TA-NWT-000020, December 1991), p. 2.

[17] Competitive risk was addressed by Moody's Investors Service (see *Telecommunications Reports* [December 6, 1993]:5) with its warning: "In addition, it says the trend toward telephone companies entering each other's local exchange markets through alliances with cable TV operators and the prospect of new wireless services have increased the competitive risk at the local loop level 'significantly.' Telco's debt ratings 'are likely to be downgraded as a result.' " The same risk to the telco's debt is faced by the telco's assets.

3.7 years.[18],[19] For existing digital circuit equipment, this ARL implies a projection life of eight to nine years for a typical company.

Exhibit 9

Adoption of SONET Equipment



Source: Technology Futures, Inc.

Lives for Analog Circuit Equipment

The analog circuit account includes analog carrier equipment and various other equipment for use in an analog environment, notably Metallic Facility Termination (MFT) equipment used for line treatment and conditioning on subscriber private-line loops and Switched Maintenance Access System (SMAS) test equipment used to test individual analog circuits.

[18] This is a conservative estimate because, in addition to SONET, there are other drivers that will cause particular types of digital circuit equipment to be retired before 2000. First, D-channel banks have been and will continue to be replaced by Digital Crossconnect Systems, as well as by direct interfaces to digital switches. Second, T-1 terminal equipment and repeaters are retired when fiber optics systems are deployed. Third, central office DLC terminals are being replaced by direct DLC interfaces into switches, which also eliminate the need for line cards on the switch.

[19] See Table 3.4 in Attachment 3 for ARL computations.

Analog carrier equipment has no economic value, but, in a few places, it has yet to be officially retired. It simply has no place in a digital network. The appropriate remaining lives of this equipment should be zero or at least very, very low.

The other analog circuit categories are also basically obsolete. Conditioned lines are usually used for private lines that carry data traffic via modems, at faster data rates than can be handled on standard lines. In many cases, digital private lines are replacing conditioned analog lines for these applications; in others, improved modems allow the same data rates over unconditioned lines. SMAS test capability is being replaced by digital circuit equipment such as Digital Access and Cross-connect Systems (DACS).

To keep things simple, we estimate the life of the entire analog circuit account by tying it to the demise of the analog central office environment, in particular the demise of analog switching for the industry. Although some companies have already replaced their analog switching, the industry ARL should be a good surrogate for the end of the analog environment. This is conservative since much of the account, especially analog carrier, will be gone before analog switching. Our forecast for analog switching, shown in Exhibit 10, yields an ARL of 2.8 years as of 1/1/95. Thus, we recommend this as the maximum reasonable life for analog circuit equipment. For a typical range of companies, this ARL corresponds to a projection life of six to nine years.

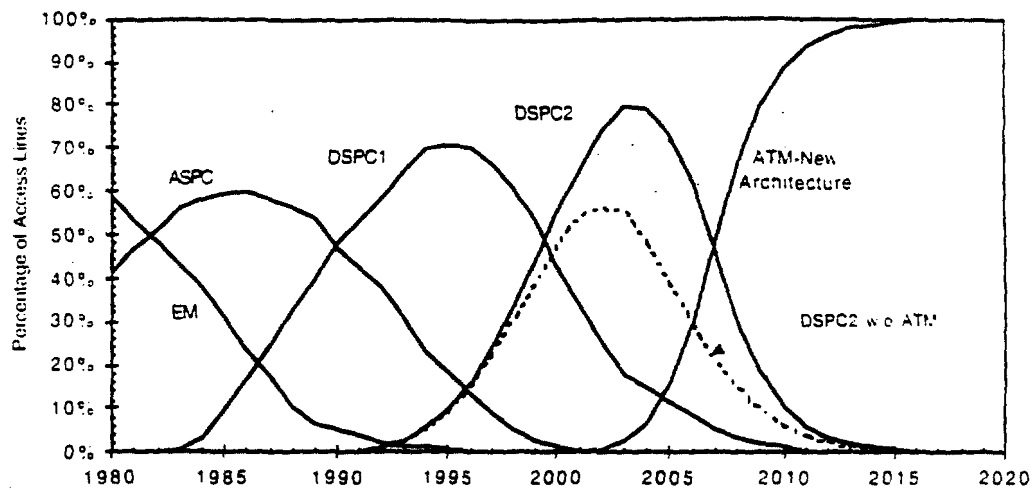
Lives for Analog Switching

Exhibit 10 shows the percentage of access lines on the major switch technology types. At year-end 1993, ASPC switching served 31% of access lines. We expect this figure to fall to 5% by 1998 and 1% by 2001. The forecasts were derived using a multiple substitution analysis of historical and planning data.[20] The forecast implies an ARL of 2.8 years for analog switching.[21]

[20] The historical data through 1989 are from TFI files. The historical data for 1990-1993 are from ARMIS reports filed with the FCC, and the planning data for 1994-1995 are the weighted average from eight LECs (representing over 100 million working channels in 1993) that provided us with planning data.

[21] See Table 3.5 in Attachment 3 for ARL computations.

Exhibit 10
Switching Technology Shares



Source: Technology Futures, Inc.

Lives for Digital Switching

There are two factors to consider in computing digital switching lives. First, digital switches use a modular architecture that allows individual components of the switch to be upgraded independently to increase capacity, improve performance, or add new features and capabilities without having to completely replace the switch. This creates interim retirements of the components that are upgraded. At the end of the life of a switch entity, most of its components will likely have been replaced at least once. Second, today's switch architectures, flexible as they are, will ultimately be replaced by a new switching architecture based on ATM.

Our approach to estimating digital switching lives is to concentrate on interim retirements. We divide the switch into its major components and estimate the life for each component using technology forecasting. Then, a composite life is estimated by weighting the component lives by their percentage of switch investment. Digital switching, being relatively new, has experienced relatively few modular changeouts so far. However, there is evidence that interim retirement rates are increasing, and our forecasts indicate that they will increase dramatically in the future.

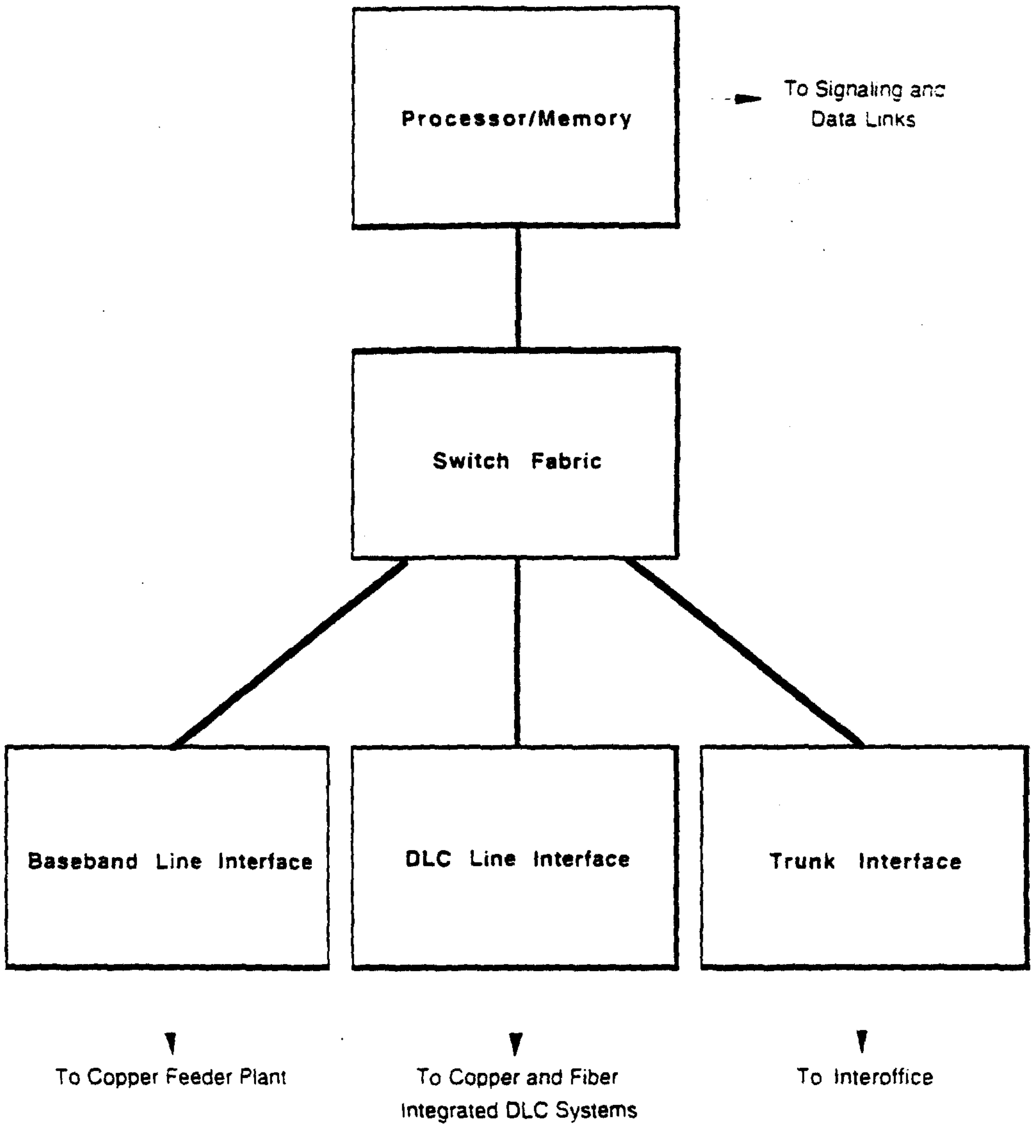
The major functional components of a digital switch are the following:

- *Central Processor/Memory*—This is basically computer equipment that provides the "brains" of the switch.
- *Switching Fabric*—This provides the very basic function of a switch: making the connections between incoming and outgoing communications channels.
- *Trunk Interfaces*—These connect the switch to interoffice transmission facilities leading to distant switches.
- *DLC Line Interfaces*—These connect the switch to DLC facilities in the loop plant.
- *Baseband Line Interfaces*[22]—These connect the switch to baseband copper loops dedicated to individual customers. (Traditionally, these provide analog POTS service, but this category includes equipment providing baseband digital services such as narrowband ISDN as well.)
- *Shell*—This is the common equipment, such as some cabling and power equipment, that is not modular and will last the life of the switch entity.[23]

Exhibit 11 illustrates how these components make up a digital switch.

[22] Technically, baseband refers to signals that are not multiplexed or modulated, where the conductors carry the signal for only a single channel. Here, we extend the definition slightly to include services such as narrowband ISDN which involves several channels from the same customer on a single copper pair.
[23] In some cases, it may include the physical housing of switch components, but often these are replaced along with the components.

Exhibit 11
Generic Switching Architecture



Source: Technology Futures, Inc.

As noted, the modularity of the digital switch creates interim retirements of the components that are upgraded. Our analysis, summarized in Exhibit 12, yields a composite ARL of 6.3 years as of 1/1/95. For *existing* equipment, this corresponds to a projection life of nine to 11 years, depending on the average age of existing equipment.

Exhibit 12
Digital Switching—Modular Retirement Analysis

Component	% of Investment	Key Drivers	ARL (years)	Composite Contribution (years)
Processor/Memory	29%	Life cycle	5.0	1.47
Switching Fabric	5%	Life cycle & ATM	8.0	0.43
Trunk Interface	12%	IO SONET + 2 yrs	4.5	0.54
DLC Line Interface	4%	Feeder SONET + 2 yrs	6.3	0.25
Baseband Line Interface	40%	DLC, FITL, & Dig Services	6.3	2.52
Shell	8%	ATM Architecture	13.3	1.06
Composite	100%	Composite ARL = (as of 1/1/95)		6.3

Source: Technology Futures, Inc.

The investment proportions shown in the exhibit are a composite of studies by several LECs. Note that the processor/memory and line interfaces represent, by far, the greatest portion of switch investment, comprising 73% of the investment in the switch, and that the shell represents less than 10%.

The component lives shown in Exhibit 12 were estimated by a combination of methods. The processor/memory life was based on a 1992 analysis of first-generation purchases and retirements for Northern Telecom switches.[24] The switch fabric life was based on our forecast for the integration of ATM into existing switches, as well as near-term changeouts. The trunk interface and DLC line interface lives were based on the SONET adoption forecasts presented earlier, with a two-year lag added to account for the delayed impact on switching. The life for the largest component, analog line interfaces, was based on forecasts of the adoption of integrated DLC and FITL, as well as the impact of new digital services, including narrowband ISDN on non-DLC access lines.

[24] L. K. Vanston, B. R. Kravitz, and R. C. Lenz, *Average Projection Lives of Digital Switching and Circuit Equipment* (Austin, TX: Technology Futures, Inc., 1992). Prepared for the United States Telephone Association (USTA).

The shell, which comprises less than 10% of the investment in a switch, is the part that is not modular and will last the life of the switch entity. The shell will be retired when ATM switches dominate the public network. Exhibit 13 shows our forecast for the percentage of access lines served by ATM switching, along with the ATM implementation method.[25] The first ATM switches in the public network are separate switches that are overlaid on the existing network. Next will come ATM as a separate switching fabric in existing switch architectures. Neither of these developments will have much impact on existing narrowband switch lives. Once certain conditions are met, voice traffic will begin to migrate to ATM. First, an ATM fabric will become the primary fabric in existing digital switches, replacing the narrowband fabric.[26] Eventually, however the entire switch entity will likely be retired. After all, today's digital switch architectures were not optimized for ATM, and they will eventually run out of steam like electromechanical and analog electronic switches have.[27] The percentage of access lines served by ATM as a new architecture is used to estimate the life of the shell. The replacement by a new architecture is not forecast to occur until after 2000, and its exact timing is subject to significant uncertainty. However, this uncertainty is not problematic in estimating digital switching lives, because the shell's percentage of the switch investment is so small.

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[25] This forecast assumes that ATM's initial application is limited to data services and ATM does not reach 1% of access lines until the end of 1996, but that, thereafter, ATM is adopted at the same average pace as digital switching was. The implementation estimates were derived from the results of a 1993 survey of network planners at nine LECs.

[26] ATM switches are incredibly fast, have tremendous capacity, and have a low cost per unit of bandwidth. As the cost gets even lower and certain other requirements are met, it will become more economical to switch voice on ATM than on traditional switching fabrics.

[27] There are several alternative scenarios for how ATM switching may be adopted. For example, narrowband services may migrate directly to new ATM switches, rather than first being implemented as primary fabrics on existing switches. Alternatively, it is possible that today's digital architectures, upgraded to ATM could prove more resilient than expected, postponing the adoption of a new architecture. Also, it is possible that narrowband services could stay on narrowband fabrics longer than expected. Finally, LECs might delay upgrades to existing digital switches in anticipation of ATM. As discussed in *Transforming the Local Exchange Network*, none of these scenarios is likely to significantly affect our estimate of composite lives for digital switching.

Exhibit 13

ATM Switching—Percentage of Access Lines

Year	Digital Switching (All Types)	FITL	ATM Switching
1993	68.0%	0.2%	0.0%
1994	76.1%	0.4%	0.1%
1995	80.6%	0.8%	0.6%
1996	86.1%	1.5%	1.0%
1997	90.2%	2.8%	1.7%
1998	94.8%	5.2%	2.7%
1999	97.3%	9.1%	4.5%
2000	98.6%	15.3%	7.2%
2001	99.3%	23.6%	11.5%
2002	99.6%	33.1%	17.8%
2003	99.8%	42.4%	26.5%
2004	99.9%	51.0%	37.5%
2005	99.9%	59.0%	50.0%
2006	100.0%	67.1%	62.5%
2007	100.0%	75.0%	73.5%
2008	100.0%	82.2%	82.2%
2009	100.0%	88.2%	88.5%
2010	100.0%	92.5%	92.8%
2011	100.0%	95.4%	95.5%
2012	100.0%	97.3%	97.3%
2013	100.0%	98.4%	98.3%
2014	100.0%	99.1%	99.0%
2015	100.0%	99.5%	99.4%

Source: Technology Futures, Inc.

Summary

The forecasts imply rapid obsolescence of the existing local telecommunications infrastructure and accelerated adoption of new technology. These changes, driven by technology advance, competition, and new services, are occurring across all major categories of network equipment. The recommended lives implied by our forecasts are summarized in the table below. These are industry averages, although they should generally apply to individual companies with modest variation. These lives are significantly shorter than those used in regulatory accounting. They reflect the realities of technological change and the need to provide advanced communications services. They do not, however, fully reflect the impact of competition on the economic life of equipment and, therefore, may still be too long.

Exhibit 14

TFI Equipment Life Recommendations

Technology	Recommended Industry Average Remaining Life (1/1/95)	Corresponding Projection Life*
Outside Plant		
Interoffice Cable, Metallic	2.9	
Feeder Cable, Metallic	7.0 to 7.8	
Distribution Cable, Metallic	7.5 to 10.2**	
Metallic Cable, Averaged	7.0 to 8.7**	14 to 16
Cable, Non-Metallic, All Types	-	15 to 20=
Circuit Equipment		
Analog	2.8	6 to 9
Digital	3.7	8 to 9
Switching Equipment		
Analog	2.8	-
Digital	6.3	9 to 11$

* These are estimates for the industry average; some companies may have lower or higher projection lives. Note: The projection life is for the installed base not newly-installed equipment, and depends on the particular distribution of plant a company has.

** Ignoring competition for voice services.

= The 15-year projection life reflects risk due to competition.

$ This is a reasonable range of projection lives for existing equipment that corresponds to the recommended industry ARL of 6.3 years. Companies with a shorter ARL may have a shorter projection life.

Attachment 1

Substitution Analysis and the Fisher-Pry Model

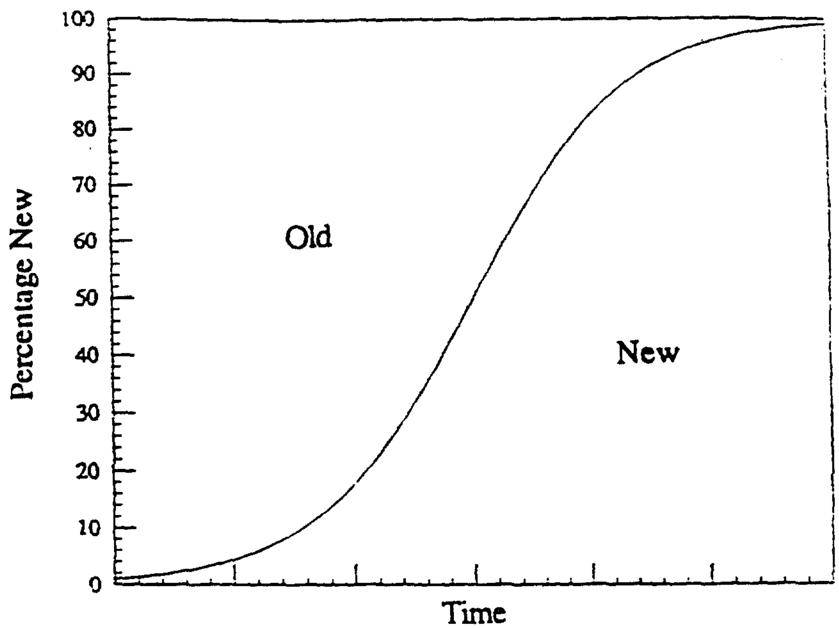
Substitution analysis examines patterns of technology substitution—a pattern which is remarkably consistent from one substitution to another. The adoption of a new technology starts slowly. As the new technology improves, it becomes generally recognized as superior. The old technology, because of inherent limitations, experiences falling market share.

If the percentage of the total market captured by a new technology is plotted over time, an S-shaped curve results. Experience shows that a particular set of models, namely the Fisher-Pry model and its extensions, is most useful for forecasting. The model was first described by Fisher and Pry in 1971.[1] It has been shown to be appropriate for substitutions in both telecommunications and other industries. More than 200 substitutions, in industries ranging from chemicals to

[1] J. C. Fisher and R. H. Pry, "A Simple Substitution Model of Technological Change," *Technological Forecasting and Social Change* 3 (1971), pp. 75-88.

aviation, have been identified that fit the Fisher-Pry pattern.[2] The S-shaped curve defined by the Fisher-Pry model is shown in Exhibit 1.1.

Exhibit 1.1
The Fisher-Pry Model



Source: Technology Futures, Inc.

Mathematically, the model can be written:

$$y(t) = 1 / (1 + e^{-b(t-a)})$$

where **y(t)** is the fraction of the new technology at time **t**. The parameter **a** is the time the new technology reaches 50% of the total universe of the old and new technology. The parameter **b** measures how fast the substitution proceeds. Another commonly-used measure for the rate of substitution is the Fisher-Pry annual substitution rate, defined as $\mathbf{r = (e^{b}-1) \times 100\%}$.

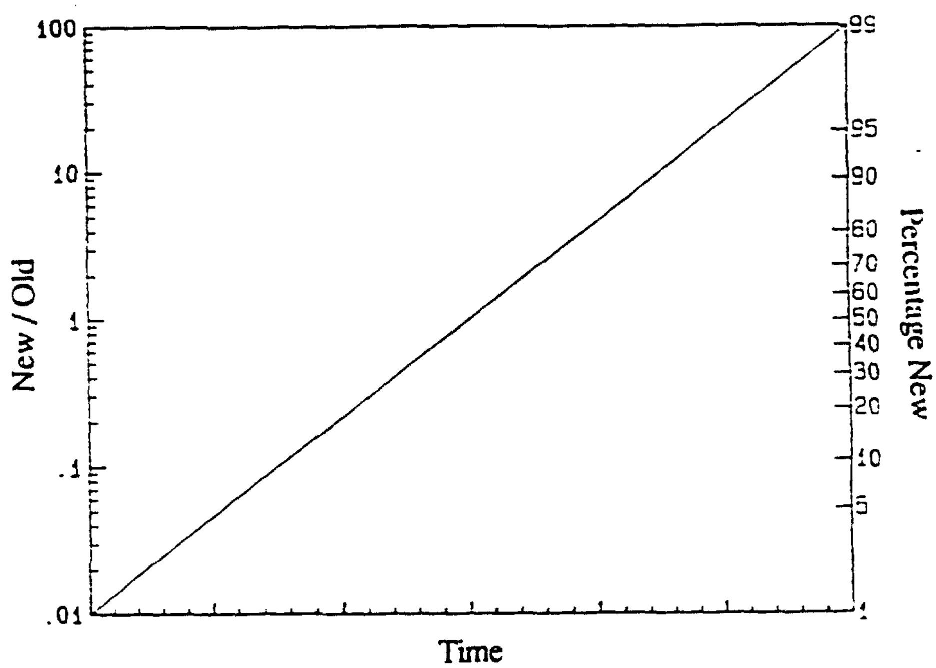
[2] R. C. Lenz and L. K. Vanston, *Comparisons of Technology Substitutions in Telecommunications and Other Industries* (Austin, TX: Technology Futures, Inc., 1986).

The shape of the curve is remarkably constant from substitution to substitution. However, the time period over which the substitution takes place varies greatly from one substitution to another. In electronics, complete substitution may occur in less than 10 years, while, in the past, complete substitution may have taken over 20 years for some telecommunications substitutions. Today, telecommunications substitutions are becoming somewhat more like those in electronics. The time period is related to the substitution rate for a particular substitution.

The ratio of the new technology to the old technology is called the Fisher-Pry ratio. Against time, the Fisher-Pry ratio plots as a straight line on a semilogarithmic graph, as shown in Exhibit 1.2.

Exhibit 1.2

Linearized Fisher-Pry Model



Source: Technology Futures, Inc.

The right-hand scale on the graph shows the market penetration of the new technology. The semilogarithmic graph is commonly used when analyzing data because it is easier to visualize than an S-shaped curve. The S-shaped curve is more often used for the presentation of results because it is easier to explain and interpret.

Forecasting with Fisher-Pry

With the Fisher-Pry model, the future course of a partially-complete substitution can be forecast. Using linear or non-linear regression analysis, historical data can be used to obtain estimates for the parameters **a** and **b**. These estimates can then be entered into the Fisher-Pry equation to obtain projections for future years.

In some cases, it is necessary to forecast the adoption of a new technology before it has begun to penetrate the market. Lacking historical data, forecasters can turn to analogies. For example, if similar historical substitutions occurred at substitution rates from 50% to 100%, one can posit that the new substitution may occur at the rate of about 75% (or 50%, to be conservative). Also, expert opinion and other forecasting techniques can be used to aid in estimating the appropriate rate.

Extensions of Fisher-Pry

In practice, not all technology substitutions exactly follow the Fisher-Pry model. For example, in some telecommunications substitutions, an early rapid rate of substitution has been observed to prevail up to the 10% level of substitution, followed thereafter by a somewhat slower rate. Beyond the 90% substitution point, the rate tends to increase again. Forecasts can be adjusted to account for this deviation by referring to historical substitutions as analogies.[3] In the case of multiple substitution (described below) and in other situations, such as capital constrained substitution, a more rigorous approach can be taken.

Multiple substitution occurs when the substitution of one technology for another is in progress and a third technology enters the market. For example, digital switching was introduced before analog electronic switches had completely replaced electromechanical switches, so both analog and digital switches were substituting for electromechanical. Research over the past nine years has

[3] For example, see Lenz and Vanston, *Comparisons*.

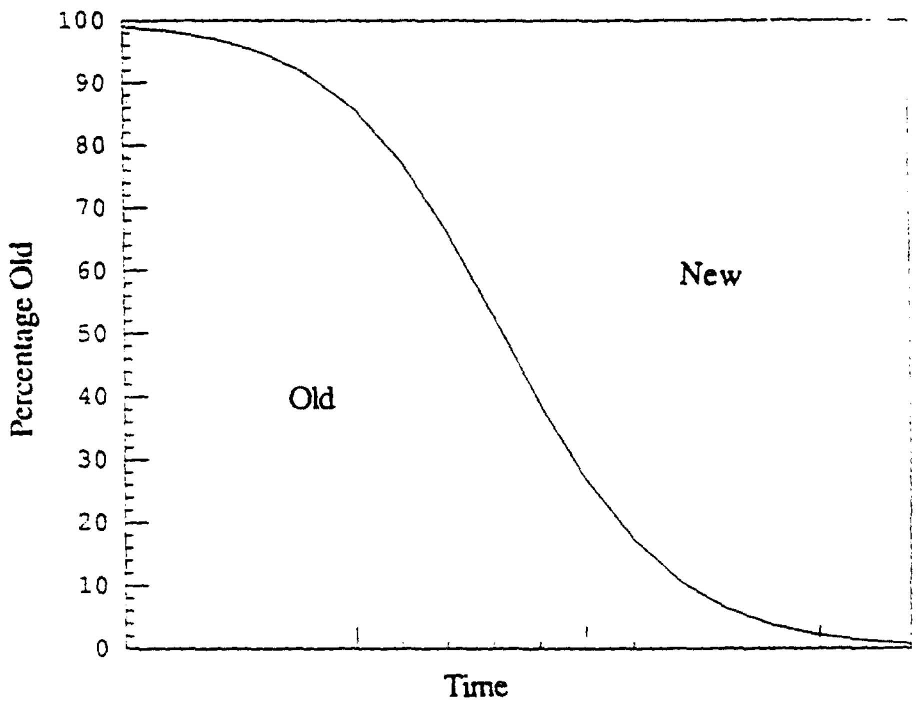
provided an improved understanding of multiple substitution, and practical techniques have been developed for dealing with it.[2]

Projecting the Market Share of the Old Technology

The market remaining for the old technology is derived by simply subtracting from 100% the percentage of new technology determined by the Fisher-Pry model. As shown in Exhibit 1.3, this is the same as reversing the S-shaped curve.

Exhibit 1.3

Market Share of the Old Technology



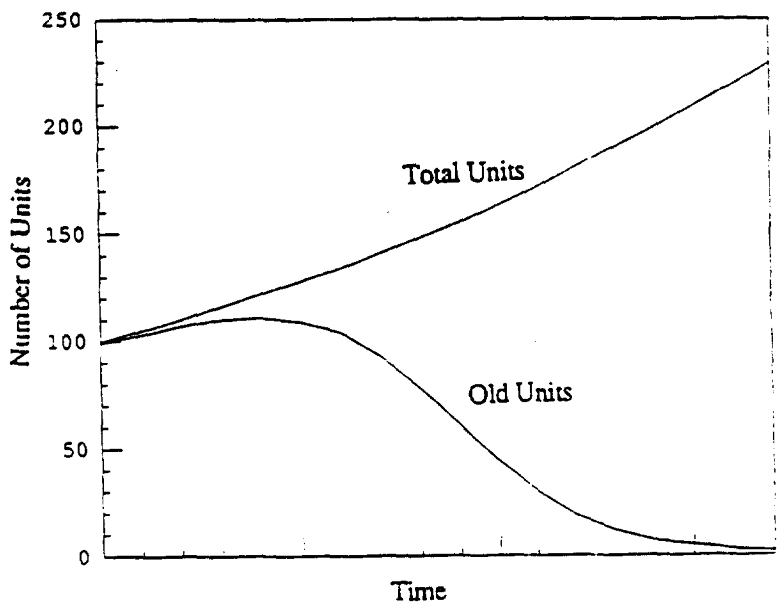
Source: Technology Futures, Inc.

[2] See John W. Keith, *Applications of the Fisher-Pry Model to Non-Homogeneous Technological Populations*, NYNEX Service Company (1987) included as Appendix H in L. K. Vanston and R. C. Lenz, *Technological Substitution in Transmission Facilities for Local Telecommunications* (Austin, TX: Technology Futures, Inc., 1988). Also, see L. K. Vanston and R. C. Lenz, *Technological Substitution in Switching Equipment for Local Telecommunications* (Austin, TX: Technology Futures, Inc., 1988), pp. 11-16.

Projecting the Number of Units

The Fisher-Pry model predicts the *percentage* of new and old technology. To calculate the *number* of units of each, an independent forecast of the total market must be made. Multiplying the total by the percentages yields the number of units of the old and new technology. Exhibit 1.4 illustrates how growth (in this case, a 5% per year growth rate) affects the number of units of the old technology. Although the old technology is losing market share, it can continue to grow for several years after the introduction of the new technology. The faster the growth relative to the substitution rate, the larger the effect.

Exhibit 1.4
Projecting the Number of Units



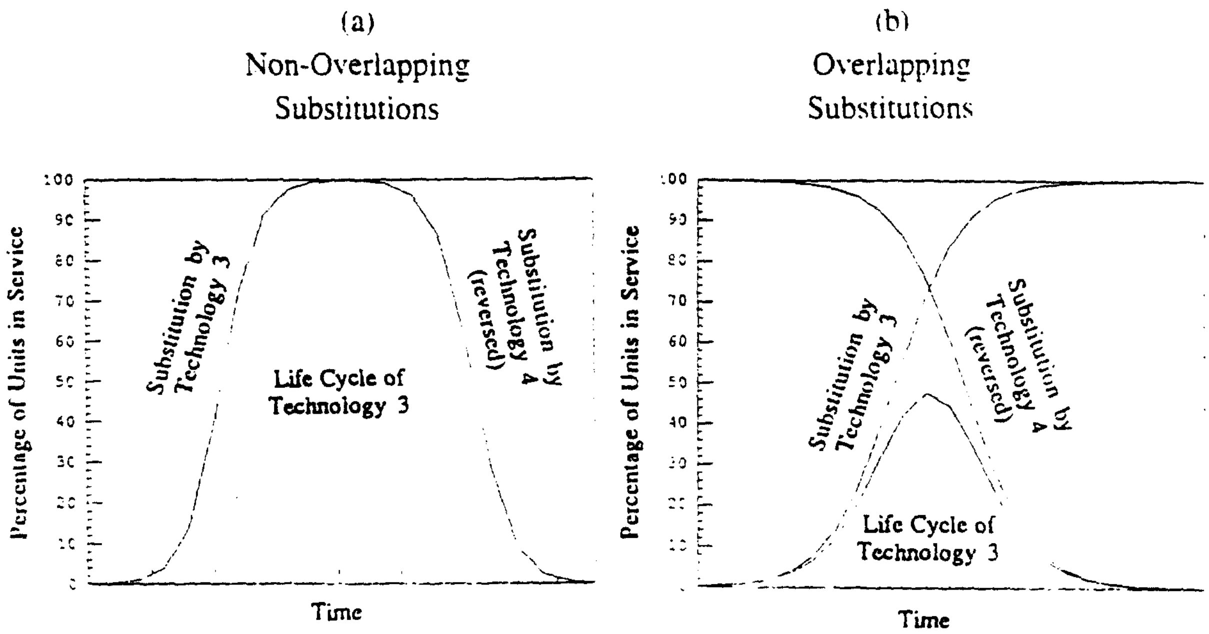
Source: Technology Futures, Inc.

Relationship to Product Life Cycles

The product life cycle shows the units of a technology in service over time. Fisher-Pry can be used to forecast the product life cycle on a percentage basis, which can then be used to state the forecast in terms of the number of units. Basically, when a technology is new, its S-shaped substitution curve forms the up side of the product life cycle. When a newer technology comes along, the reverse of its S-shaped substitution curve forms the down side of the product life cycle for the earlier technology. This process is illustrated in Exhibit 1.5a. This simple explanation applies only when the substitutions do not overlap, i.e., the first substitution is complete before the second begins. This situation is now rare in the electronics, computer, and telephone industries, where new technologies come on the heels of one another. For overlapping substitutions, the connection between the S-shaped substitution curves and the life cycles is more complicated, as indicated in Exhibit 1.5b.[5]

Exhibit 1.5

Fisher-Pry and Life Cycles



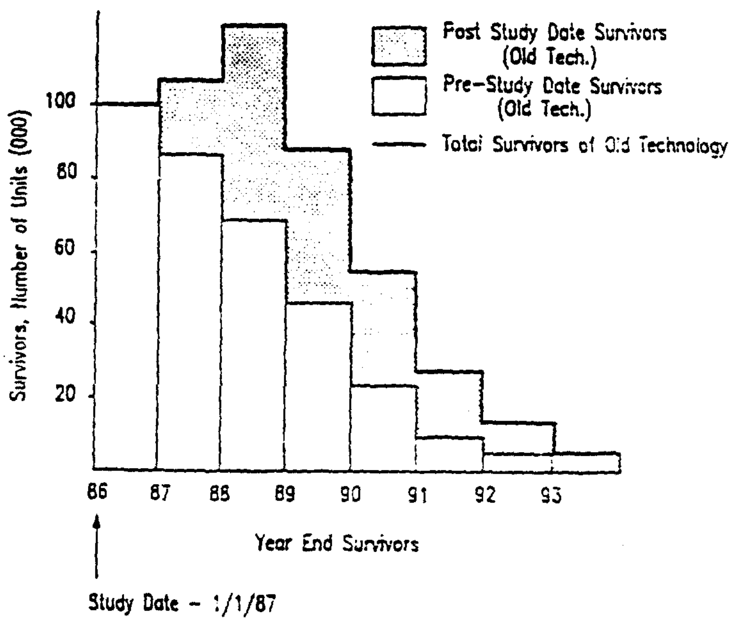
Source: Technology Futures, Inc.

[5] A more detailed explanation is given in Appendix A of L. K. Vanston, B. R. Kravitz, and R. C. Lenz, *Average Projection Lives of Digital Switching and Circuit Equipment* (Austin, TX: Technology Futures, Inc., 1992).

Forecasting Depreciation Lives

Fisher-Pry substitution analysis can be used to forecast end dates for an old technology, which can then be incorporated into a standard depreciation analysis. Fisher-Pry can also be used to help derive the survivor curve from which the average remaining life (ARL) of the old technology can be calculated. This process involves several steps. First, the forecast must be stated in terms of the units of old technology, as discussed above. This curve includes all survivors of the old technology, while the survivor curve applies only to equipment in place as of the study date. Thus, to obtain the survivor curve, we must subtract the additions of the old technology that are added after the study date, as well as equipment retired due to normal mortality as illustrated in Exhibit 1.6.[6]

Exhibit 1.6
Computing the Survivor Curve



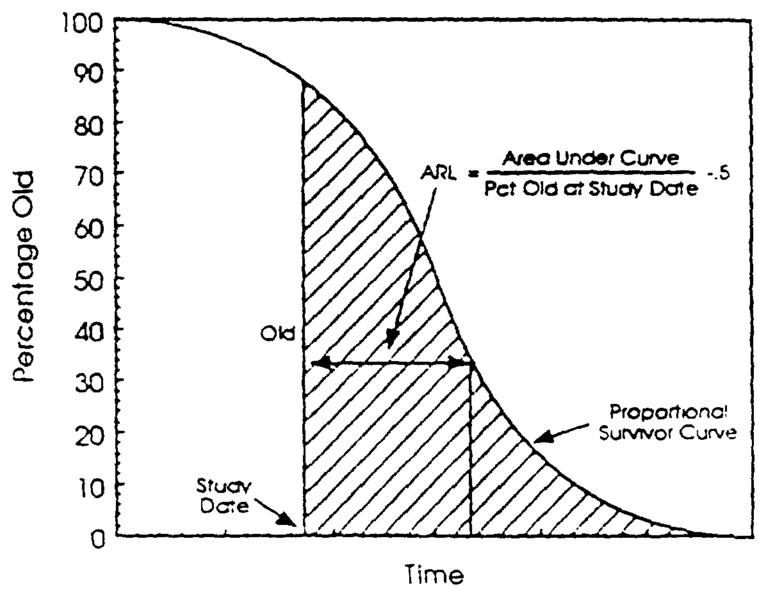
Source: Technology Futures, Inc.

[6] For more details, see TechOver[TM] manual (Austin, TX: Technology Futures, Inc., 1987), pp. 8.1-8.10.

For general studies, a reasonable estimate of ARL can be obtained by using the proportional curve directly, as illustrated in Exhibit 1.7. Neglecting growth may cause the ARL to be underestimated by about a year, while neglecting retirements due to normal retirements can cause the ARL to be overestimated by about as much. These factors tend to balance each other and, thus, forecasters get a good estimate unless the growth rate is extremely high or normal retirements are especially low.

Exhibit 1.7

Estimating the Average Remaining Life from the Old Technology Market Share



Source: Technology Futures, Inc.

Company Forecasts

Substitution analysis can be applied to both an individual company's data or to industry data. Naturally, industry data, spread over a larger population, tends to produce smoother curves. Also, individual companies may lag the industry substitution, but toward the end of the substitution, they tend to increase their rate of substitution and catch up with the industry. This has the effect of causing the entire industry to have essentially the same end-date and keeps the industry on the Fisher-Pry curve.[7] This observation is not surprising, since a company cannot stay competitive (or in business) if it fails to keep up with its competitors in the adoption of more efficient technology.

[7] R. C. Lenz and L. K. Vanston, *The Effects of Various Levels of Aggregation in Technology Substitutions* (Austin, TX: Technology Futures, Inc., 1987).

Attachment 2

List of TFI Publications

Technology's Impact on Lives of Telecommunications Equipment at New York Telephone. Technology Futures, Inc. (1985).

Comparisons of Technology Substitutions in Telecommunications and Other Industries. Ralph C. Lenz and Lawrence K. Vanston (1986).

The Effects of Various Levels of Aggregation in Technology Substitutions. Ralph C. Lenz and Lawrence K. Vanston (1987).

Technological Substitution in Transmission Facilities for Local Telecommunications. Lawrence K. Vanston and Ralph C. Lenz (1988).

Technological Substitution in Switching Equipment for Local Telecommunications. Lawrence K. Vanston and Ralph C. Lenz (1989).

Technological Substitution in Circuit Equipment for Local Telecommunications. Lawrence K. Vanston (1989).